Proc. Instn Civ. Engrs, Part 2, 1978, **65**, Dec., 967–971

8080 DISCUSSION

Model tests of circular sewage sedimentation tanks

I. F. CHRISTIE & R. W. HARBINSON

Dr T. H. Y. Tebbutt, Department of Civil Engineering, University of Birmingham

The Authors' results on the effect of initial concentration of suspended solids on percentage removal (as shown in Fig. 3) agree with the observations made on pilot scale tanks at the University of Birmingham. In this work[30] the influence of initial suspended solids on removal was found to be more significant than hydraulic loading (or retention time) over a wide range of loadings. There was clear evidence that the sewage contained a fairly constant concentration of non-settleable suspended solids regardless of the level of total suspended solids. Using the performance relationships developed for the Birmingham data for a tank 2·5 m deep, predicted suspended solids removals for a 2 hour retention time are shown in Fig. 7, together with the Authors' curve for quiescent column settlement from Fig. 3. The Authors' studies show greater removals in the tanks than were obtained from the column tests but the similarities in the behaviour of the two sewages are of interest.

58. A difficulty inherent in the use of suspended solids as a performance parameter in sedimentation was related to the fact that only a proportion of these solids was settleable. Unfortunately this proportion could vary over a considerable range in sewage from a single source. Presentation of sedimentation results in terms of percentage removal of suspended solids could thus sometimes be misleading. Did the Authors also determine settleable solids? The results for the alternative inlet configurations summarized in Table 3 show fairly marked differences in performance although Tables 1 and 2 indicate that the mean inlet suspended solids concentration for the cylinder tests was greater than for the plates in all three groups of tests with the large model. Some improvement in performance of the cylinder type could therefore be attributed to these higher inlet solids concentrations.

59. Will the effect of density currents in the greater depth of the full-scale tank modify the behaviour of the inlet? Are follow-up studies on the performance of the actual tanks being considered?

60. There is evidence that the usual design criteria for primary sedimentation tanks are rather conservative; the collection of performance data for both suspended and settleable solids removal from full-scale tanks operating with retention times of 2 hours or less would be of value.

Mr M. S. Clements, Department of Civil and Structural Engineering, University of Sheffield

In view of the finding that the best model results were obtained with a clearance of only 76 mm between the baffle and the tank floor (an inlet ratio of 8) it would have been

Paper published: *Proc. Instn Civ. Engrs*, Part 2, 1978, **65**, Mar., 71–84.

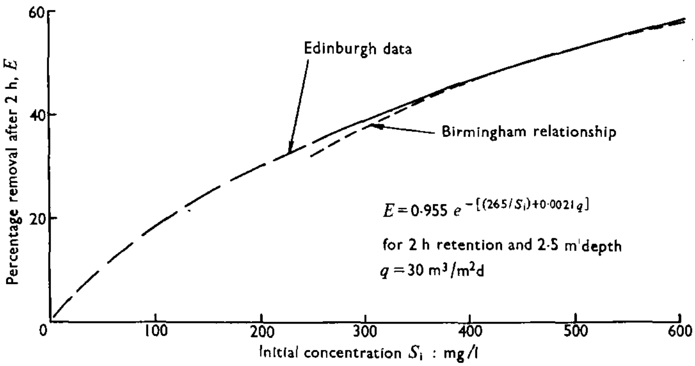

Fig. 7

interesting to see the way in which performance varied with inlet ratio for comparison with the graphs given in reference 24. In tests carried out at Sheffield, both for time ratio measurement and discrete particle removal, the best results were consistently obtained with an inlet ratio of about 1·3. One possible explanation for the difference lies in the fact that the Sheffield tests were carried out with models operated at a reasonably high Reynolds number to ensure turbulent flow patterns in the model. Price[31, 32] has shown that this practice results in good agreement with the patterns in the full-scale tanks which were modelled, although Emery[33] has shown that departure from geometric modelling of the inlet in some rectangular tanks is advisable in order to improve the similarity of flow pattern.

62. With the surface loading chosen as the modelling criterion and a model of 1/6 full scale, the Reynolds number obtained is only 1/6 of that in the full-scale tank. Using the surface loading figure of 46·2 m^3/m^2d quoted in reference 1, with a temperature of 14°C, the Reynolds number at maximum flow in the full-scale tanks is about 11 300. At the range of flows quoted in the Paper (5·7–28·3 l/s) and at a temperature of 20°C the corresponding model Reynolds numbers range from only 350 to 1780, and with the loading rate of 35 m^3/m^2d used in Table 1 the highest value is 1685. All these assume baffles in the model. Reference 24 shows that a Reynolds number of 1600 gave different results from those obtained in tests at 2600. Values over 2000 were considered to be necessary to simulate patterns at full scale.

63. However, the change in time ratio, which might be achieved by cutting off the lower part of the baffle in one of the full-scale tanks to give the inlet ratio of 1·3, will have much less effect on the performance of the tank than will the improved removal due to the increased depth. This is referred to in § 51; the improvement can be quantified in three stages.

64. The most important requirement in using static column tests is the basing of the results on column depths corresponding to the tank to be used—in this case 3·83 m. Because the concentration of suspended solids at any time is almost independent of depth, I use the data in Fig. 1 to illustrate this point. (In tests with sewage and humus at ten different works and column depths from 1 m to 3 m I have confirmed that this statement is approximately true and consider it is a useful working hypothesis for extrapolation of the Authors' results.) Table 4 uses the mean values of suspended solids at 15, 30, 60 and 120 minutes for column depths of 0·60 m, 1·50 m and 3·83 m. The first set of results is appropriate for use with the Author's model, the second is appropriate to neither the model nor the full-scale tank (although it has apparently been used for both) and the third, although extrapolated and therefore synthetic, serves as an

Table 4

Approximate mean concentration, mg/l	Time, s	Percentage settling faster	Velocity for 0·6 m, mm/s	Velocity for 1·5 m, mm/s	Velocity for 3·83 m, mm/s
555	0	—	—	—	—
435	900	21·6	0·667	1·667	4·256
285	1800	48·6	0·333	0·833	2·128
255	3600	54·1	0·167	0·417	1·064
195	7200	64·9	0·083	0·208	0·532

illustration of the kind of result which might be expected from tests in a column 3·83 m deep which would be appropriate for use as a guide to performance in the full-scale tank.

65. These values are plotted (full lines) as the settling velocity curves for the three depths in Fig. 8. The second step is to obtain from these curves the actual removal curves, taking account of partial removal of slower settling particles, as recommended by Camp.[3] These are plotted as broken lines. For any value of effective loading rate (velocity) given by division of the nominal loading rate by the time ratio, it is seen that a greater removal will be obtained in the full-scale tank than in the model. Increases of the time ratio value achieved by inlet improvements decrease the effective loading rate and so result in improvements in removal. However, in this example these improvements are much less than those attributable to the increased depth. With a time ratio of 0·70, equal to the best value measured in a full-scale circular tank during my research, the effective upward velocity in the full-scale tanks at Edinburgh can be expected to reach about 0·76 mm/s at maximum flow rate.

66. In the third stage of estimation of removal some allowance must be made for

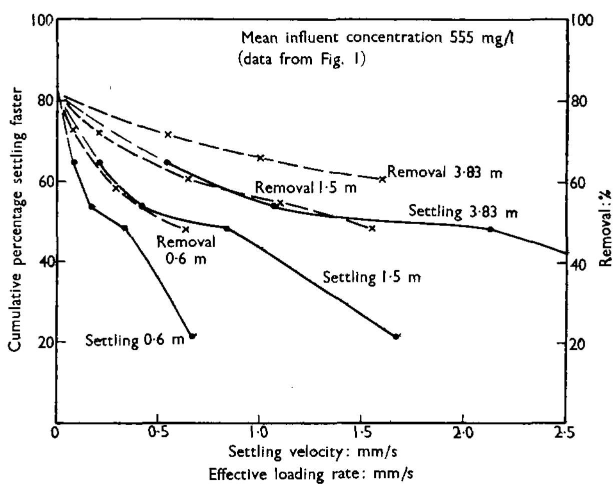

Fig. 8

the improvement over the static column results which is due to extra flocculation in the full-scale tanks by the turbulent shear effects. At the same time the effect of variation of suspended solids content needs to be taken into account. Guidance on these aspects on the basis of comparisons between results of column tests and full-scale tank tests (circular and rectangular) at ten different sewage works is given in reference 34.

67. It is considered that if all three stages are carried out and the time ratio is known fairly approximately a realistic estimate of the performance of any tank should be obtainable.

Dr Christie and Mr Harbinson

The influence of initial concentration of suspended solids on percentage removal in quiescent columns and in continuous flow tanks was emphasized in the Paper. Dr Tebbutt's comparison with results obtained at Birmingham is interesting although the closeness of fit is rather fortuitous as the conditions of settlement are dissimilar (quiescent columns and continuous flow tank).

69. In quiescent column tests at Edinburgh suspended solids continued to be removed throughout a 24 hour settling period. Hence there is a difficulty in defining settleable solids. During the first series of tank tests this was not fully appreciated and additional tests were made with the intention of measuring settleable solids at inlet and outlet. In these tests 50 ml samples were stored in test tubes for two hours, after which supernatent water, containing solids still in suspension, was decanted and the settled solids were measured by filtration. In view of its arbitrary nature and variable results this test was later abandoned in favour of quiescent column tests carried out simultaneously with the tank tests.

70. Dr Tebbutt has drawn attention to the higher average concentration of suspended solids at inlet in the final tests with the cylindrical baffle. As the order of testing the two types of inlet was usually reversed from one test to the next there is no obvious reason for this result. On average the difference amounted to just under 10% and only a small improvement in tank performance could be attributed to this. Moreover, the settleability of the sewage was not determined solely by its initial concentration of suspended solids—hence the scatter in Fig. 3. It therefore seemed more appropriate to base comparisons on the corresponding quiescent column test results.

71. In reply to Mr Clements it is not possible to give a useful comparison on the effect of inlet ratio. Bearing in mind the variability of the sewage, the number of tests with different cylindrical baffles was insufficient for this purpose. The final series of tests involved inlets outside the range previously tested at Sheffield.

72. Difficulties in scaling, including consideration of Reynolds number, are discussed in the Paper. A compromise involving a large model was adopted initially and some guidance on the scale effect was obtained later by comparing results obtained at two scales. These proved that equal surface rating did not lead to the same performance at different scales and indicated that detention period and settleability of the sewage were most important.

73. In § 51 the improvement in performance with size of tank, assuming operation at the same surface rating, was attributed to increase in detention period. Mr Clements has interpreted this as a depth effect and has described a method of predicting tank performance from quiescent column results. Such a method is potentially useful and deserves further study. However, the values in Table 4 have been calculated by a method outlined by Camp[3] for use with discrete particles and Camp states that this cannot be used for flocculent suspensions because the particles do not retain constant settling velocities. Furthermore, Camp's method of obtaining removal curves from settling velocity curves assumes an ideal settling tank. This might apply to tanks with a Hubbell type inlet but it does not apply to those with a deep cylindrical baffle.

74. It is intended to continue this research with further quiescent column tests and measurements in the full-scale tanks.

References

30. TEBBUTT T. H. Y. and CHRISTOULAS D. G. Performance relationships for primary sedimentation. *Wat. Res.*, 1975, **9**, 347–356.
31. PRICE G. A. *Influence of inlet changes, wind effects and density currents in rectangular sedimentation tanks.* PhD thesis, University of Sheffield, 1970.
32. PRICE G. A. and CLEMENTS M. S. Some lessons from model and full-scale tests in rectangular sedimentation tanks. *Wat. Pollut. Control*, 1974, **73**, No. 1, 102–113.
33. EMERY W. H. *Flow characteristics of rectangular sedimentation tanks.* PhD thesis, University of Sheffield, 1976.
34. CLEMENTS M. S. The application of static column tests to sedimentation tank design. *Wat. Pollut. Control*, 1976, **75**, No. 3, 360–376.